Chapter 7

Automation

Introduction

In the general aviation (GA) community, an automated aircraft is generally comprised of an integrated advanced avionics system consisting of a primary flight display (PFD), a multifunction display (MFD) including an instrument-certified global positioning system (GPS) with traffic and terrain graphics, and a fully integrated autopilot. This type of aircraft is commonly known as an advanced avionics aircraft. In an advanced avionics aircraft, the PFD is displayed on the left computer screen and the MFD is on the right screen.

Automation is the single most important advance in aviation technologies. Electronic flight displays (EFDs) have made vast improvements in how information is displayed and what information is available to the pilot. Pilots can access onboard information electronically that includes databases containing approach information, primary instrument display, and moving maps that mirror sectional charts, or display modes that provide three-dimensional views of upcoming terrain. These detailed displays depict airspace, including temporary flight restrictions (TFRs). MFDs are so descriptive that many pilots fall into the trap of relying solely on the moving maps for navigation. *[Figure 7-1]*

Figure 7-1. *Electronic flight instrumentation comes in many systems and provides a myriad of information to the pilot.*

More pilots now rely on automated flight planning tools and electronic databases for flight planning rather than planning the flight by the traditional methods of laying out charts, drawing the course, identifying navigation points (assuming a visual flight rules (VFR) flight), and using the pilot's operating handbook (POH) to figure out the weight and balance and performance charts. Whichever method a pilot chooses to plan a flight, it is important to remember to check and confirm calculations.

Most of the aviation community believes automation has made flying safer, but there is a fear that pilots fail to see that automation is a double-edged sword. Pilots need to understand the advantages of automation while being aware of its limitations. Experience has shown that automated systems can make some errors more evident while sometimes hiding other errors or making them less obvious. In 2005, the British Airline Pilots Association (BALPA) raised concerns about the way airline pilots are trained to depend upon automation. BALPA felt the current training leads to a lack of basic flying skills and inability to cope with an inflight emergency, especially mechanical failures. The union believes passenger safety could be at risk.

Cockpit Automation Study

Concerns about the effect of automation on flight skills are not new. In 1995, the erosion of manual flight skills due to automation was examined in a study designed by Patrick R. Veillette and R. Decker. Their conclusions are documented in "Differences in Aircrew Manual Skills and Automated and Conventional Flightdecks," published in the April 1995 edition of the Transportation Research Record, an academic journal of the National Research Council. In the February 2006 issue of Business and Commercial Aviation (BCA), Dr. Patrick R. Veillette returned to this topic in his article "Watching and Waning."

The Veillette-Decker seminal study on automation came at a time when automated flight decks were entering everyday line operations and concern was growing about some of the unanticipated side effects. Deterioration of basic pilot skills was one of these concerns. While automation made the promise of reducing human mistakes, in some instances it actually created larger errors. When this study was undertaken, the workload in an automated flight deck in the terminal environment actually seemed higher than in the older conventional flight decks. At other times, automation seemed to lull the flight crews into complacency. Fears arose that the manual flying skills of flight crews using automation deteriorated due to an overreliance on computers. In fact, BALPA voiced a fear that has dogged automation for years: that pilots using automation have less "stick and rudder" proficiency when those skills were needed to resume direct manual control of the aircraft.

Thus, the Veillette-Decker study sought to determine what, if any, possible differences exist in manual flight skills between aircrews assigned to conventional and automated flight decks. Limited to normal and abnormal operations in terminal airspace, it sought to determine the degree of difference in manual flying and navigational tracking skills. Commercial airline crew members flying the conventional transport aircraft or the automated version were observed during line-oriented flight training.

The data set included various aircraft parameters such as heading, altitude, airspeed, glideslope, and localizer deviations, as well as pilot control inputs. These were recorded during a variety of normal, abnormal, and emergency maneuvers during 4-hour simulator sessions. All experimental participants were commercial airline pilots holding airline transport pilot certificates. The control group was composed of pilots who flew an older version of a common twin-jet airliner equipped with analog instrumentation. The experimental group was composed of pilots who flew newer models of that same aircraft equipped with a first generation electronic flight instrument system (EFIS) and flight management system (FMS).

When pilots who had flown EFIS for several years were required to fly various maneuvers manually, the aircraft parameters and flight control inputs clearly showed some erosion of flying skills. During normal maneuvers, the EFIS group exhibited somewhat greater deviations than the conventional group. Most of the time, the deviations were within the Practical Test Standard (PTS), but the pilots definitely did not keep on the localizer and glideslope as smoothly as the conventional group. The differences in hand-flying skills between the two groups became more significant during abnormal maneuvers such as steeper than normal visual approaches (slam-dunks).

Analysis of the aircraft data consistently had pilots of automated aircraft exhibit greater deviations from assigned courses and aircraft state parameters, and greater deviations from normal pitch and bank attitudes, than the pilots of conventional flight deck aircraft. *[Figure 7-2]* The most significant differences were found to occur during the approach and landing phases. It is industry practice to tolerate very little air speed deviation from the recommended value during approach and landing. The FAA's Practical Test Standards (PTS) for the airline transport rating allow a final approach speed of no more than five knots faster than recommended.

Another situation used in the simulator experiment reflected real world changes in approach that are common and can be assigned on short notice. While a pilot's lack of familiarity with the EFIS is often an issue, the approach would have been made easier by disengaging the automated system and manually flying the approach.

The emergency maneuver, engine-inoperative instrument landing system (ILS) approach, continued to reflect the same performance differences in manual flying skills between the two groups. The conventional pilots tended to fly raw data and when given an engine failure, they performed it expertly. When EFIS crews had their flight directors disabled, their eye scan began a more erratic searching pattern and their manual flying subsequently suffered. According to Dr. Veillette's 2005 article, those who reviewed the data "saw that the EFIS pilots who better managed the automation also had better flying skills."

While the Veillette-Decker study offers valuable information on the effects of cockpit automation on the pilot and crew, experience now shows that increased workloads from advanced avionics results from the different timing of the manual flying workloads. Previously, the pilot(s) were busiest during takeoff and approach or landing. With the demands of automation programming, most of the workloads have been moved to prior to takeoff and prior to landing. Since Air Traffic Control (ATC) deems this the most appropriate time to notify the pilot(s) of a route or approach change, a flurry of reprogramming actions occurs at a time when management of the aircraft is most critical.

Reprogramming tasks during the approach to landing phase of flight can trigger aircraft mishandling errors that in turn snowball into a chain of errors leading to incidents or accidents. It does not require much time to retune a VOR for a new ILS, but it may require several programming steps to change the ILS selection in an FMS. In the meantime, someone must fly or monitor and someone else must respond to ATC instructions. In the pilot's spare time, checklists should be used and configuration changes accomplished and checked. Almost without exception, it can be stated that the faster a crew attempts to reprogram the unit, the more errors will be made.

Since publication of the Veillette-Decker study, increasing numbers of GA aircraft have been equipped with integrated advanced program avionics systems. These systems can lull pilots into a sense of complacency that is shattered by an inflight emergency. Thus, it is imperative for pilots to understand that automation does not replace basic flying skills. Automation adds to the overall quality of the flight experience, but it can also lead to catastrophe if not utilized properly. A moving map is not meant to substitute for a VFR sectional or low altitude en route chart. When using automation, it is recommended pilots use their best judgment and choose which level of automation will most efficiently do the task, considering the workload and situational awareness.

Pilots also need to maintain their flight skills and ability to maneuver aircraft manually within the standards set forth in the PTS. It is recommended that pilots of automated aircraft occasionally disengage the automation and manually fly the aircraft to maintain stick-and-rudder proficiency. In fact, a major airline recommends that their crews practice their instrument approaches in good weather conditions and use the autopilot in the bad weather conditions and monitor the flight's parameters.

More information on potential automation issues can be found at the flight deck automation issues website: www.flightdeckautomation.com. This website includes a searchable database containing over 1,000 records of data that support or refute 94 issues with automated flying.

Realities of Automation

Advanced avionics offer multiple levels of automation from strictly manual flight to highly automated flight. No one level of automation is appropriate for all flight situations, but in order to avoid potentially dangerous distractions when flying with advanced avionics, the pilot must know how to manage the course deviation indicator (CDI), navigation source, and the autopilot. It is important for a pilot to know the peculiarities of the particular automated system being used. This ensures the pilot knows what to expect, how to monitor for proper operation, and promptly take appropriate action if the system does not perform as expected.

For example, at the most basic level, managing the autopilot means knowing at all times which modes are engaged and which modes are armed to engage. The pilot needs to verify that armed functions (e.g., navigation tracking or altitude capture) engage at the appropriate time. Automation management is another good place to practice the callout

Figure 7-2. *Two flight decks equipped with the same information but in two different formats: analog and digital. What are they indicating? Chances are that the analog pilot will review the top display before the bottom display. Conversely, the digitally trained pilot will review the instrument panel on the bottom first.*

technique, especially after arming the system to make a change in course or altitude.

In advanced avionics aircraft, proper automation management also requires a thorough understanding of how the autopilot interacts with the other systems. For example, with some autopilots, changing the navigation source on the Electronic Horizontal Situation Indicator (e-HSI) from GPS to localizer (LOC) or VOR while the autopilot is engaged in NAV (course tracking mode) causes the autopilot's NAV mode to disengage. The autopilot's lateral control defaults to wings level until the pilot takes action to reengage the NAV mode to track the desired navigation source.

Enhanced Situational Awareness

An advanced avionics aircraft may offer increased safety with enhanced situational awareness. Although aircraft flight manuals (AFM) explicitly prohibit using the moving map, topography, terrain awareness, traffic, and weather datalink displays as the primary data source, these tools nonetheless give the pilot unprecedented information for enhanced situational awareness. Without a well-planned information management strategy, these tools also make it easy for an unwary pilot to slide into the complacent role of passenger in command.

Consider the pilot whose navigational information management strategy consists solely of following the magenta line on the moving map. He or she can easily fly into geographic or regulatory disaster if the straight line GPS course goes through high terrain or prohibited airspace or if the moving map display fails.

Risk is also increased when the pilot fails to monitor the systems. By failing to monitor the systems and failing to check the results of the processes, the pilot becomes detached from aircraft operation. This type of complacency led to tragedy in a 1999 aircraft accident in Colombia. A multi-engine aircraft crewed by two pilots struck the face of the Andes Mountains. Examination of their FMS revealed they entered a waypoint into the FMS incorrectly by one degree, resulting in a flightpath taking them to a point 60 nautical miles (NM) off the intended course. The pilots were equipped with the proper charts, their route was posted on the charts, and they had a paper navigation log indicating the direction of each leg. They had all the tools to manage and monitor their flight, but instead allowed the automation to fly and manage itself. The system did exactly what it was programmed to do; it flew on a programmed course into a mountain, resulting in multiple deaths. The pilots simply failed to manage the system and created their own hazard. Although this hazard was self-induced, what is notable is the risk the pilots created through their own inattention. By failing to evaluate each turn made at the direction of automation, the pilots maximized risk instead of minimizing it. In this case, an avoidable accident became a tragedy through simple pilot error and complacency.

Not only did the crew fail to fully monitor the aircraft's automated routing, they also failed to retract the spoilers upon adding full thrust. This prevented the aircraft from outclimbing the slope of the mountain. Simulations of the accident indicate that had the aircraft had automatic spoiler retraction (spoilers automatically retract upon application of maximum thrust), or if the crew had remembered the spoilers, the aircraft probably would have missed the mountain.

Pilots en route to La Paz unwittingly deselected the very low frequency (VLF) input, thereby rendering the automation system unreliable. Although the system alerted the pilots to the ambiguity of navigation solution, the pilots perceived the alert to be computer error, and followed the course it provided anyway. They reached what they thought should be La Paz, but which was later estimated to have been approximately 30 NM away. They attempted to execute the published approach but were unable to tune the VOR radio, so they used instead the VLF of the KNS 660 to guide them on an impromptu approach. They were unable to gain visual contact with the runway environment due to in-cloud conditions despite the reported weather being clear with unrestricted visibility. Then they proceeded to their alternate about 1½ hours away. After 2½ hours of flight and following what they thought was the proper course, the aircraft became fuel critical, necessitating a controlled let-down from FL 250 to presumably visually conditions. Ironically, at about 9,000 mean sea level (MSL) they broke out of the cloud cover above an airfield. Although they attempted to align themselves for the runway, the aircraft ran out of fuel. The pilots dead-sticked the King Air to a ramp after which they broke through a fence, went over a berm, and into a pond. The aircraft was destroyed. After exiting the aircraft relatively unscathed, they found out they landed in Corumba, Brazil. *[Figure 7-3]*

In this accident, the pilots failed to realize that when no Omega signals were available with the VLF/Omega system, the equipment could continue to provide a navigation solution with no integrity using only the VLF system. Although the VLF/Omega system is now obsolete and has been replaced by the Global Navigation Satellite System (GNSS) and Loran-C, this accident illustrates the need for pilots of all experience levels to be thoroughly familiar with the operation of the avionics equipment being used. A pilot must not only know and understand what is being displayed, but must also be aware of what is not being displayed.

Figure 7-3. *The pilots of a King Air 200 had a flight from Bogota, Colombia, to Iquitos, Peru, (for fuel) and then to La Paz, Bolivia, as final destination. They listed Viru Viru (located at Santa Cruz, Bolivia) as their alternate. The aircraft was equipped with a Bendix King KNS 660 that provided integrated navigation solutions based upon VOR, DME, and two variants of VLF radios. At that time, GPS had not yet been integrated into the FMS.*

A good strategy for maintaining situational awareness of information management should include practices that help ensure that awareness is enhanced by the use of automation, not diminished. Two basic procedures are to always double-check the system and conduct verbal callouts. At a minimum, ensure the presentation makes sense. Was the correct destination fed into the navigation system? Callouts—even for single-pilot operations—are an excellent way to maintain situational awareness, as well as manage information.

Other ways to maintain situational awareness include:

- Performing a verification check of all programming. Before departure, check all information programmed while on the ground.
- Checking the flight routing. Before departure, ensure all routing matches the planned flight route. Enter the planned route and legs, to include headings and leg length, on a paper log. Use this log to evaluate what has been programmed. If the two do not match, do not assume the computer data is correct, double check the computer entry.
- Verifying waypoints.
- Making use of all onboard navigation equipment. For example, use VOR to back up GPS and vice versa.
- Matching the use of the automated system with pilot proficiency. Stay within personal limitations.

- Planning a realistic flight route to maintain situational awareness. For example, although the onboard equipment allows a direct flight from Denver, Colorado, to Destin, Florida, the likelihood of rerouting around Eglin Air Force Base's airspace is high.
- Being ready to verify computer data entries. For example, incorrect keystrokes could lead to loss of situational awareness because the pilot may not recognize errors made during a high workload period.

Autopilot Systems

In a single-pilot environment, an autopilot system can greatly reduce workload. *[Figure 7-4]* As a result, the pilot is free to focus attention on other flight deck duties. This can improve situational awareness and reduce the possibility of a controlled flight into terrain (CFIT) accident. While the addition of an autopilot may certainly be considered a risk control measure, the real challenge comes in determining the impact of an inoperative unit. If the autopilot is known to be inoperative prior to departure, this may factor into the evaluation of other risks.

Figure 7-4. *An example of an autopilot system.*

For example, the pilot may be planning a VOR approach down to minimums on a dark night into an unfamiliar airport. In such a case, the pilot may have been relying heavily on a functioning autopilot capable of flying a coupled approach. This would free the pilot to monitor aircraft performance. A malfunctioning autopilot could be the single factor that takes this from a medium to a serious risk. At this point, an alternative needs to be considered. On the other hand, if the autopilot were to fail at a critical (high workload) portion of this same flight, the pilot must be prepared to take action. Instead of simply being an inconvenience, this could quickly turn into an emergency if not properly handled. The best way to ensure a pilot is prepared for such an event is to study the issue carefully prior to departure and determine well in advance how an autopilot failure is to be handled.

Familiarity

As previously discussed, pilot familiarity with all equipment is critical in optimizing both safety and efficiency. A pilot's being unfamiliar with any aircraft system will add to workload and may contribute to a loss of situational awareness. This level of proficiency is critical and should be looked upon as a requirement, not unlike carrying an adequate supply of fuel. As a result, pilots should not look upon unfamiliarity with the aircraft and its systems as a risk control measure, but instead as a hazard with high risk potential. Discipline is the key to success.

Respect for Onboard Systems

Automation can assist the pilot in many ways, but a thorough understanding of the system(s) in use is essential to gaining the benefits it can offer. Understanding leads to respect, which is achieved through discipline and the mastery of the onboard systems. However, it is important to fly the airplane without complete reliance on the PFD. This includes turns, climbs, descents, and flying approaches.

Reinforcement of Onboard Suites

The use of an electronic flight display (EFD) may not seem intuitive, but competency becomes better with understanding and practice. Computer-based software and incremental training help the pilot become comfortable with the onboard suites. Then, the pilot needs to practice what was learned in order to gain experience. Reinforcement not only yields dividends in the use of automation, it also reduces workload significantly.

Getting Beyond Rote Workmanship

The key to working effectively with automation is getting beyond the sequential process of executing an action. If a pilot has to analyze what key to push next, or always uses the same sequence of keystrokes when others are available, he or she may be trapped in a rote process. This mechanical process indicates a shallow understanding of the system. Again, the desire is to become competent and know what to do without having to think about "what keystroke is next." Operating the system with competency and comprehension benefits a pilot when situations become more diverse and tasks increase.

Understand the Platform

Contrary to popular belief, flight in aircraft equipped with different electronic management suites requires the same attention as aircraft equipped with analog instrumentation and a conventional suite of avionics. The pilot should review and understand the different ways in which EFDs are used in a particular aircraft. *[Figure 7-5]*

Figure 7-5. *Examples of different platforms. Top to bottom are the Beechcraft Baron G58, Cirrus SR22, and Cessna Entegra.*

Two simple rules for use of an EFD:

- Fly the aircraft to the standards in the PTS. Although this may seem insignificant, knowing how to fly the aircraft to a standard makes a pilot's airmanship smoother and allows for more time to attend to the system instead of managing multiple tasks.
- Read and understand the installed electronic flight system's manuals to include the use of the autopilot and the other onboard electronic management tools.
- Adhere to AFM/POH procedures.

Flight Management Skills

Automation Management

Before any pilot can master aircraft automation, he or she must first know how to fly the aircraft. Maneuver training remains an important component of flight training because almost 40 percent of all GA accidents take place in the landing phase, one realm of flight that still does not involve programming a computer to execute. Another 15 percent of all GA accidents occur during takeoff and initial climb.

An advanced avionics safety issue identified by the FAA concerns pilots who apparently develop an unwarranted overreliance in their avionics and the aircraft, believing that the equipment compensates for pilot shortcomings. Related to that overreliance is the role of ADM, which is probably the most significant factor in the GA accident record of high performance aircraft used for cross-country flight. The FAA advanced avionics aircraft safety study found that poor decision-making seems to afflict new advanced avionics pilots at a rate higher than that of GA as a whole. The review of advanced avionics accidents cited in this study shows the majority are not caused by something directly related to the aircraft, but by the pilot's lack of experience and a chain of poor decisions. One consistent theme in many of the fatal accidents is continued VFR flight into IMC.

Thus, pilot skills for normal and emergency operations hinge not only on mechanical manipulation of the stick and rudder, but also include the mental mastery of the EFD. Three key flight management skills are needed to fly the advanced avionics safely: information, automation, and risk.

Information Management

For the newly transitioning pilot, the PFD, MFD, and GPS/VHF navigator screens seem to offer too much information presented in colorful menus and submenus. In fact, the pilot may be drowning in information, but unable to find a specific piece of information. It might be helpful to remember these systems are similar to computers that store some folders on a desktop and some within a hierarchy.

The first critical information management skill for flying with advanced avionics is to understand the system at a conceptual level. Remembering how the system is organized helps the pilot manage the available information. It is important to understand that learning knob-and-dial procedures is not enough. Learning more about how advanced avionics systems work leads to better memory for procedures and allows pilots to solve problems they have not seen before.

There are also limits to understanding. It is impossible to understand all of the behaviors of a complex avionics system. Knowing to expect surprises and to continually learn new things is more effective than attempting to memorize mechanical manipulation of the knobs. Simulation software and books on the specific system used are of great value.

The second critical information management skill is to sense what is going on. Pilots new to advanced avionics often become fixated on the knobs and try to memorize each and every sequence of button pushes, pulls, and turns. A far better strategy for accessing and managing the information available in advanced avionics computers is to stop, look, and read. Reading before pushing, pulling, or twisting can often save a pilot some trouble.

Once in front of the display screens on an advanced avionics aircraft, the pilot must manage and prioritize the information flow to accomplish specific tasks. Certificated flight instructors (CFIs), as well as pilots transitioning to advanced avionics, will find it helpful to corral the information flow. This is possible through such tactics as configuring the aspects of the PFD and MFD screens according to personal preferences. For example, most systems offer map orientation options that include "north up," "track up," "desired track (DTK) up," and "heading up." Another tactic is to decide, when possible, how much (or how little) information to display. Pilots can also tailor the information displayed to suit the needs of a specific flight.

Information flow can also be managed for a specific operation. The pilot has the ability to prioritize information for a timely display of exact information needed for any given flight operation. Examples of managing information display for a specific operation include:

- Programming map scale settings for en route versus terminal area operation.
- Utilizing the terrain awareness page on the MFD for a night or IMC flight in or near the mountains.
- Using the nearest airports inset on the PFD at night or over inhospitable terrain.
- Programming the weather datalink set to show echoes and METAR status flags.

Risk Management

Risk management is the last of the three flight management skills needed for mastery of the advanced avionics aircraft. The enhanced situational awareness and automation capabilities offered by a glass flight deck vastly expand its safety and utility, especially for personal transportation use. At the same time, there is some risk that lighter workloads could lead to complacency.

Humans are characteristically poor monitors of automated systems. When passively monitoring an automated system for faults, abnormalities, or other infrequent events, humans perform poorly. The more reliable the system is, the worse the human performance becomes. For example, the pilot monitors only a backup alert system, rather than the situation that the alert system is designed to safeguard. It is a paradox of automation that technically advanced avionics can both increase and decrease pilot awareness.

It is important to remember that EFDs do not replace basic flight knowledge and skills. They are a tool for improving flight safety. Risk increases when the pilot believes the gadgets compensate for lack of skill and knowledge. It is especially important to recognize there are limits to what the electronic systems in any light GA aircraft can do. Being pilot in command (PIC) requires sound ADM, which sometimes means saying "no" to a flight.

For the GA pilot transitioning to automated systems, it is helpful to note that all human activity involving technical devices entails some element of risk. Knowledge, experience, and flight requirements tilt the odds in favor of safe and successful flights. The advanced avionics aircraft offers many new capabilities and simplifies the basic flying tasks, but only if the pilot is properly trained and all the equipment is working properly.

Pilot management of risk is improved with practice and consistent use of basic and practical risk management tools.

Chapter Summary

The advantages of automation are offset by its limitations. Accident data are used to explain enhanced situational awareness.